An Electric Lighting, Power, and Pumping Plant for the Lick Observatory.

The Observatory has always been behind the times in the matter of an adequate supply of electric current. The plans for the institution were made in the late seventies and carried out in the early eighties, before it was known what electricity would do, or that it would become a necessity, and an electric plant was not included in the installation. Partly to remedy this defect, the Edison Electric Company presented a three-horse-power plant to the Observatory in 1892. It included a steam-engine and boiler, a one-kilowatt generator, and a small storage battery. This has been indispensable in the scientific work, and for many years has been drawn upon every clear night, on many occasions at a dozen different points in the observing-rooms. However, the capacity of the plant has long since been outgrown, even for exclusively scientific purposes. The work frequently suffers, both in quantity and quality, from the shortage in the supply of current. Facts bearing upon this and other points are brought out in the following paragraphs.

The Crossley dome, set up on Mt. Hamilton in 1895, moves unduly hard, and its operation is a serious tax upon the physical strength of the observers. This dome should be operated by means of an electric motor. The winding of the clock which propels the Crossley reflector has also been a wasteful tax upon the observers' strength, and this work should be done by electric power. Current is needed to illuminate the circles and the guiding mechanism of the telescope and for various other minor purposes in the dome.

The 75-foot steel dome covering the 36-inch refractor is operated by a triple hydraulic engine. This system is only fairly satisfactory, in that the speed of the dome is too slow, the engine requires very frequent attention to keep it in adjustment, and every few years demands a general overhauling. Electric motive power would save valuable time and be more economical in maintenance. The automatic winding device for the driving-clock of this telescope is operated by the same hydraulic system. This device has been in use for two years, and has been very valuable. Nevertheless, it has required frequent attention and repair, due to the fact that the automatic opening and closing of the water-valve is a violent operation.

A satisfactory system can not be installed until electricity is available for power.

The quantity of current which can be drawn upon to maintain the spectroscopes at a constant temperature is entirely too small, and the efficiency of the work suffers in consequence. When the temperature in the great dome falls rapidly, the spectroscopic work must stop for the time, and the enforced idleness of the telescope is uneconomical.

The photometric observations of stars demand a current of constant intensity. This is not practicable with the present small supply.

Current is needed in various other parts of the main building, in the Crocker dome, and elsewhere, for scientific purposes; but it is not at present available.

The Observatory buildings, including all the residences, are illuminated by kerosene lamps. This system is unsatisfactory for many reasons. The work demanded of the janitor and others to fill the lamps and keep them in order is a serious tax. More important still is the element of danger from fire. Our fire risks are unusually great, on account of the general use of lamps and matches, of the proximity of the buildings to each other, and of the prevalence of high winds. The subject is on my mind literally from week to week, and every precaution to guard against the danger is taken; but the greatest source of danger should be removed by the substitution of electric illumination.

Small power plants have been installed here and there to perform our heavy work as required, and they are of various kinds. For example, the water used for domestic and photographic purposes is pumped from the spring into the distributing reservoirs by means of steam generated with wood fuel. For many reasons this work should be done by electric power generated at a central station. Another complete system of waterworks, which supplies power for moving the great dome and its floor, is operated by wind power. This system is satisfactory as to the moving floor, except in the months when there is little wind. During these months the supply in the distributing reservoirs is low, and nearly every fall is entirely exhausted. The result is that work with the great telescope sometimes practically ceases for a week or more in the best sea-

son of the year, and—what is far more serious—when the reservoirs are empty, the Observatory is without adequate fire protection. A pump operated by electric current from a central plant should be installed at once, and be ready to lift water to the distributing reservoirs when the wind fails.

Fuel for the Observatory is purchased in the form of four-foot wood from the neighboring ranchers, who cannot be prevailed upon to supply it in shorter lengths. The Observatory workmen cut the wood into the desired lengths by means of a buzz-saw operated by a separate steam plant.

The machine tools in the instrument-making and carpenter shops are operated by a gasoline engine. Small pieces of work are occasionally performed by means of the current leading directly from the present little generator. At least a dozen small primary batteries are maintained at various points to supply special needs.

The drinking-water system, obtaining its supply from the spring, is of sufficient capacity in ordinary years, provided great care is exercised to avoid all leaks in the pipes; but in years of small rainfall the supply is inadequate. On three occasions in recent years the shortage of rainfall made it necessary for us to reduce to the lowest limits the quantity which could be used for domestic and photographic purposes.

A perfectly practicable method exists for increasing the present supply several fold. One of the largest springs in this vicinity is located on the south slope of the peak which carries the storage reservoirs for drinking-water, at a level 680 feet lower than that of the reservoir, and at a distance of only 1,400 feet down the slope. A responsible pump manufacturer guarantees that an automatic pump, located at a point two hundred feet in level below the spring, will be able to lift one seventh of the total flow up to the reservoirs, the remaining six sevenths being required to operate the pump. Last year the flow in June was approximately fifty thousand gallons per day, and in July thirty-six thousand a day. The daily flow at the end of the last dry season, which was of unusual length, placed it at eighteen thousand gallons. If one seventh of these amounts can be placed in the distributing reservoirs, the necessary demand of the Observatory will be fully met, as the average daily consumption heretofore has been less than two thousand gallons.

With the spring upon which we depend at present held in reserve, there would be little doubt that a considerable surplus of available water would exist, even in years of low rainfall. Should this prove to be the case, plans would be instituted to cover the bare slopes immediately surrounding the Observatory with forest trees. An attempt to develop shade-trees in the early years of the Observatory failed because they could not be irrigated during the dry season. This question is of considerable importance from the scientific point of view. There is little doubt that our atmospheric conditions for observational work, already excellent, would be still better if shade-trees covered the ground. They would prevent the excessive heating in the daytime of the rock and soil surrounding the Observatory, and the consequent rapid radiation of heat in the evening.

It requires no argument to establish that our heterogeneous systems for supplying power and illumination should be replaced by a simple and central electric plant, operated by a gasoline engine. The officers of the General Electric Company have most generously examined into all the above-mentioned requirements and have drawn up plans to meet them, making no charge for the expert services of their engineers. The subject was brought to the attention of the University of California authorities, who petitioned the Governor and the Legislature of the State to make a special appropriation of ten thousand dollars for the expense of installation. This appropriation was generously made at the recent session and the construction will begin at once.

March, 1905. W. W. CAMPBELL.

NOTE ON THE ORBIT OF COMET *e* 1904.

In an address on "The General Applicability of the Short Method of Determining Orbits from Three Observations," delivered before the Astrometry Section of the International Congress of Arts and Science at St. Louis in September of last year, a criterion was given which makes it possible to decide in the case of a newly discovered planet or comet the limits within which the elements may lie. Comet *e* 1904 (BORRELLY) having been found to be periodic by AITKEN and others from longer arcs, the criterion has been applied to the